COST AND PERFORMANCE REPORT

Pump and Treat of Contaminated Groundwater at the
Solid State Circuits Superfund Site
Republic, Missouri

September 1998

Prepared by:

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office

SITE INFORMATION

Identifying Information:

Solid State Circuits (SSC) Superfund Site
Republic, Missouri

CERCLIS #: MOD9808854111

ROD Date: September 27, 1989

Treatment Application:

Type of Action: Remedial

Period of operation: 1993 - Ongoing
(Data collected through March 1997.)

Quantity of material treated during application: 257,149,396 gallons of groundwater as of March 1997.

Background

Historical Activity that Generated Contamination at the Site: Manufacturing of printed circuit boards

Corresponding SIC Code: 3571 (Electronic Computers)

Waste Management Practice That Contributed to Contamination: Storage of stripper and plating wastes in sump pit in the basement.

Facility Operations [1,2]:

- The site is located in the town of Republic, Missouri and occupies a lot that is approximately 0.5 acres in a primarily urban area.

- The site operated as Solid State Circuits (SSC) from 1968 through November 1973. During this time, SSC manufactured circuit boards and used trichloroethene (TCE) as a cleaning solvent in portions of its manufacturing process. Since that date, the site was occupied by a number of tenants, including Micrographics, Inc., a photographic processing firm, and a factory outlet store. In November 1979, a fire partially destroyed the building, and the debris was pushed into the basement under the remaining portion of the building.

- In June 1982, the Missouri Department of Natural Resources (MDNR) collected samples from of Republic's three municipal wells for analysis of volatile organic compounds as part of EPA's National Synthetic Organic Chemical Survey. Elevated concentrations of TCE were detected in one municipal well, located 500 feet from the former SSC site. Periodic sampling in the three municipal wells over the next three years consistently revealed elevated TCE concentrations in the well closest to the site; no TCE was detected in two other municipal wells nor in two additional wells installed by the City of Republic since the start of the RI/FS.

- In 1984, MDNR investigated the former manufacturing facility in an attempt to identify the source of contamination in the municipal well. Samples of soils and debris from pipes and sumps in the basement, as well as from a 540-foot deep well found in the basement, were collected. Elevated levels of TCE were found in the fill dirt and rubble excavated from the basement, in the basement well, and in the shallow groundwater outside of the building.

- In 1984, MDNR removed 75 to 150 cubic yards of TCE-contaminated soils from the basement and recased the upper 40 feet of the basement well in the hopes of using it as an extraction well. The well yield was very low and the well was plugged per state regulations. In 1985, EPA excavated and removed an additional 1,400 cubic yards of contaminated soil from within and below the basement.

- In June 1987, SSC began the Remedial Investigation/Feasibility Study. Between June and December 1987, a number of activities were performed, including a

SITE INFORMATION (CONT.)

Background (Cont.)

survey of the sewer system and private wells in the area. Monitoring wells were installed and a dual-tower air stripper was installed to treat groundwater pumped from on-site extraction wells.

- The site was placed on the National Priorities List (NPL) on June 10,1986.

Regulatory Context:
- The Record of Decision was signed on September 27, 1989.
- The EPA, MDNR, and SSC signed a Consent Decree in July 1990, requiring SSC to conduct design, construction, and operations activities for the groundwater cleanup under DNR supervision. The Consent Decree was entered in May 1991.
- Site activities are conducted under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) §121, and the National Contingency Plan (NCP), 40 CFR 300.

Groundwater Remedy Selection: An expansion of the existing system of groundwater extraction and treatment via air stripping was selected as the remedy for this site as the most cost-effective approach.

Site Logistics/Contacts

Site Lead: State

Oversight: EPA

Remedial Project Manager:
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Treatment System Operator:
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Facility Engineer:
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MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

Contaminant Characterization [2]

Primary Contaminant Groups: Volatile Organic Compounds

- Contaminants of greatest concern at the site are 1,1-dichloroethane (1,1-DCA), 1,1-dichloroethylene (1,1-DCE), *trans*-1,1-dichloroethylene (*trans*-1,1-DCE), methylene chloride, 1,1,1-trichloroethane (TCA), trichloroethylene (TCE), and vinyl chloride. TCE was reported at concentrations several orders of magnitude greater than the contaminant with the next largest concentration.

- TCE contamination was found during the RI/FS in the three groundwater units beneath the site at both on- and off-site locations. Maximum TCE concentrations detected in the surficial, or Unconsolidated Fractured Shallow Bedrock (UFSB), unit ranged from 300 µg/L near Highway 60 (approximately 1,000 feet downgradient) to 40,000 µg/L on site. The on-site maximum concentration in the intermediate, or Unfractured Shallow Bedrock (SBR), unit was 290,000 µg/L, and the highest concentrations in this unit were found between 150 and 300 feet below ground surface (bgs). The maximum on-site concentration of TCE found in the deep, or Deep Bedrock (DBR), unit was 18,000 µg/L, with the highest concentration found between 400 and 500 feet bgs.

- Significant effort has been expended to detect dense, nonaqueous phase liquid (DNAPL) at this site. No direct physical, chemical, or visual evidence has been reported from the site. Nevertheless, concentrations of TCE found during the RI are well above 1 percent of solubility, and high concentrations persist in localized extraction wells, two indicators of subsurface source zones.

- Figures 1 through 3 show the TCE plumes in each groundwater unit, respectively, in 1989. The plume in the surficial unit is controlled by a fracture zone, and, in 1989, contamination was restricted to a narrow area less than 50 feet wide, 10 feet deep, and extending approximately 1,500 feet downgradient. The plume in the intermediate unit had not migrated far from the point of release and was estimated to be no greater than 100 feet in length with highest concentrations found between 150 and 300 feet bgs. In the deep unit, the plume was estimated to extend 785 feet downgradient and to be 500 feet wide. The initial volumes of contaminated groundwater contained in the three units were estimated in 1989 to be 15 million, 790,000, and 42 million gallons, respectively.

MATRIX DESCRIPTION (CONT.)

Matrix Characteristics Affecting Treatment Costs or Performance

Hydrogeology [2]:

The groundwater system at the SSC site is characterized as a leaky artesian system occurring in karst formations with shallow bedrock and deep bedrock zones separated by a semiconfining shale layer. Groundwater flow is vertical as well as lateral. There is an interconnection between the fracture zone in the UFSB and nearby Robert Spring/Shuyler Creek but no contamination has been detected in the spring or the creek [2]. There are three principal units in the groundwater system.

Unit 1	USFB	Unconsolidated material formed of reddish-brown clay interspersed with a layer of weathered coarse crystalline limestone. Water yield is low and aquifer is not a significant source of drinking water
Unit 2	SBR	Consolidated limestone formations with fractures that can significantly impact flow velocity and direction. It is interconnected to some degree with the overlying overburden materials.
Unit 3	DBR	Confined aquifer composed of dolomite and sandstone formations. This is the principal drinking water source in the area.

Tables 1 and 2 present technical aquifer information and technical well data, respectively. A discussion of extraction wells is included in the next section.

Table 1. Technical Aquifer Information

Unit Name	Thickness (ft)	Conductivity (ft/day)	Average Velocity (ft/day)	Flow Direction
UFSB	1 - 15	0.0000001 - 0.01	Not Available	Consistent with surface water flow
SBR	250 - 300	0.023	0.0009	Southeast
DBR	1,000 - 1,500	1.62	0.43	Southeast

Source: [2]

MATRIX DESCRIPTION (CONT.)

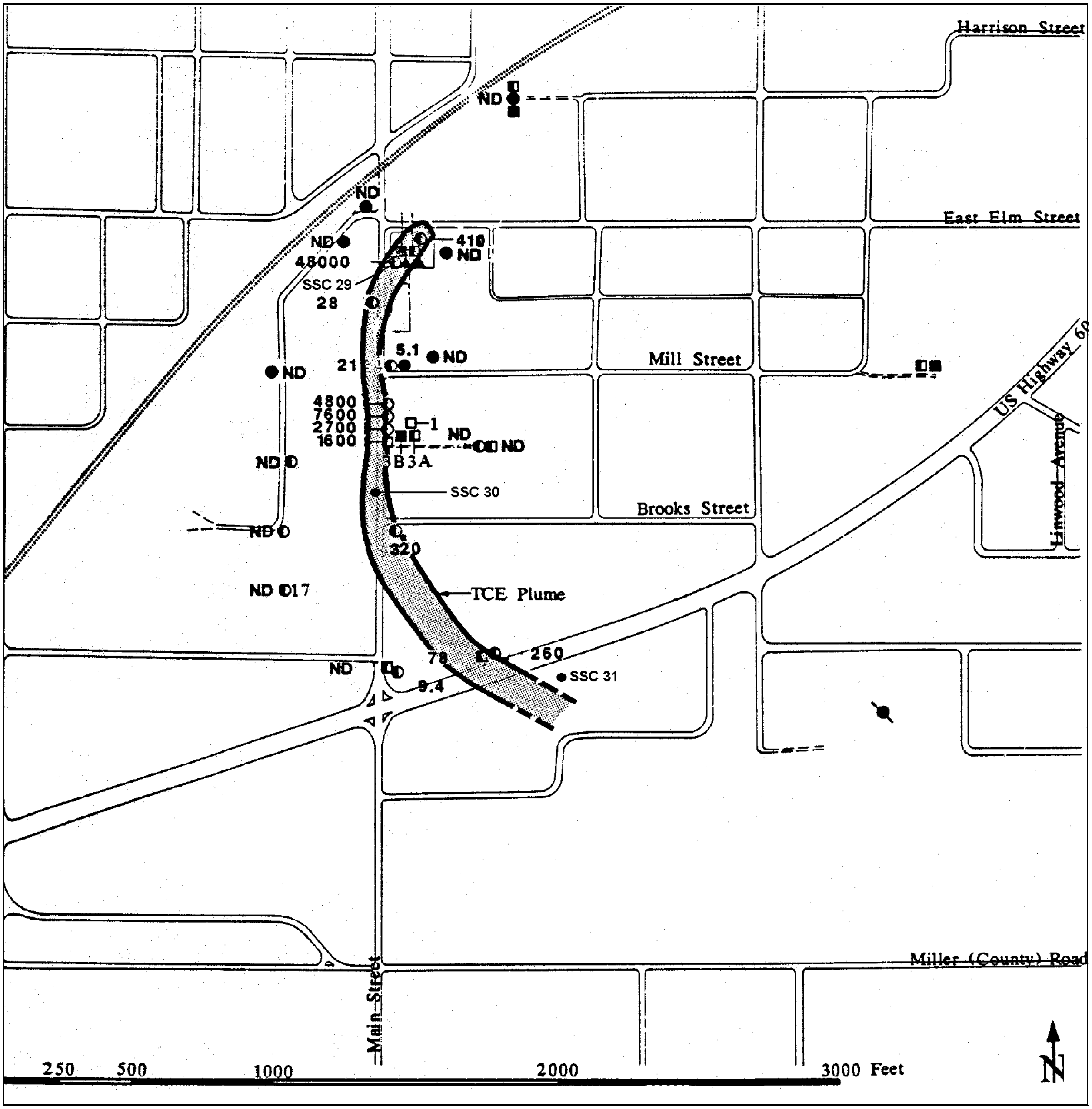

Figure 1. Initial Concentration Contour (μg/L) Map of Unconsolidated Fractured Bedrock, June 1989 [1]

MATRIX DESCRIPTION (CONT.)

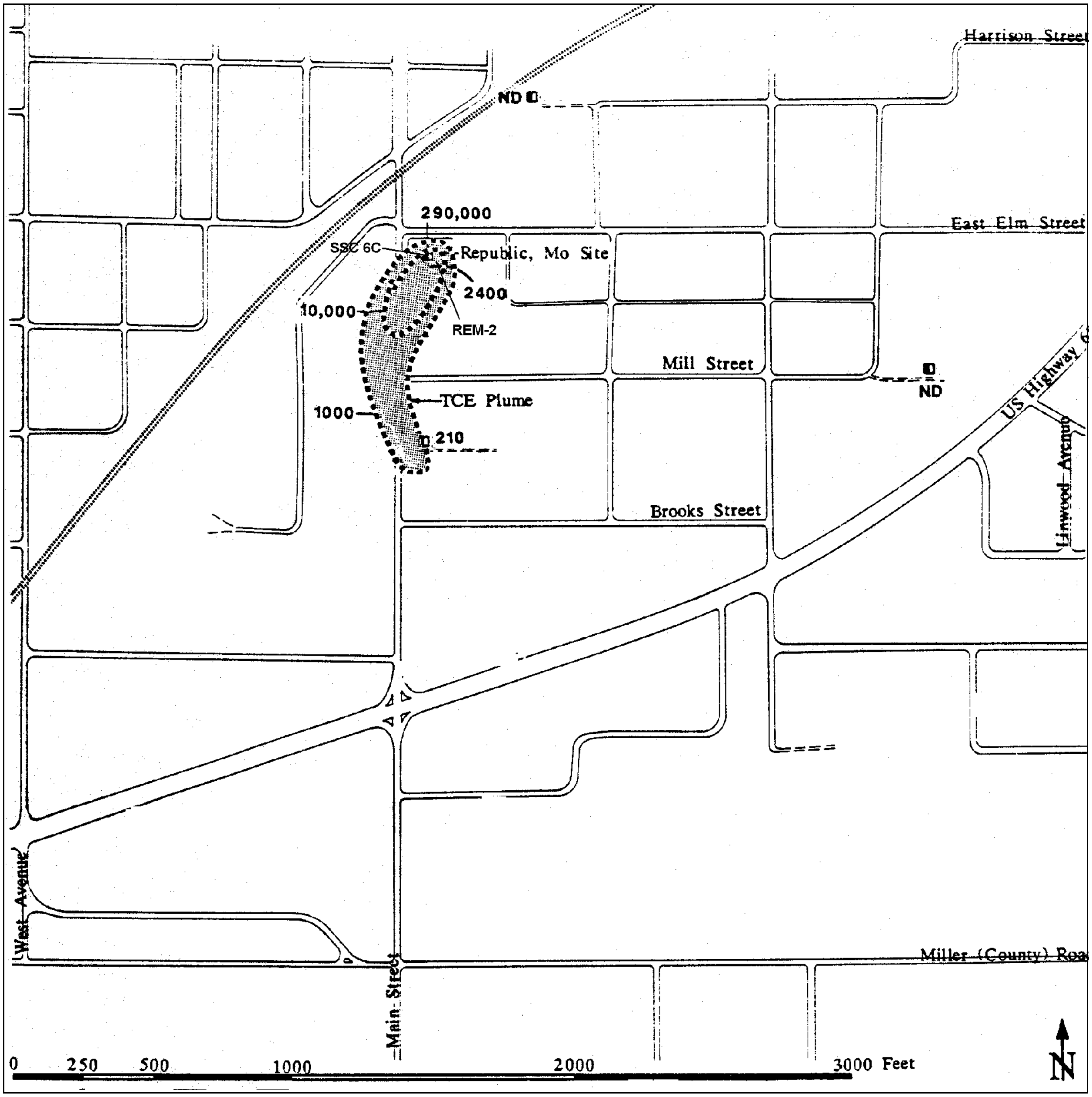

Figure 2. Initial Concentration Contour (μg/L) Map of Unfractured Shallow Bedrock, June 1989 [1]

MATRIX DESCRIPTION (CONT.)

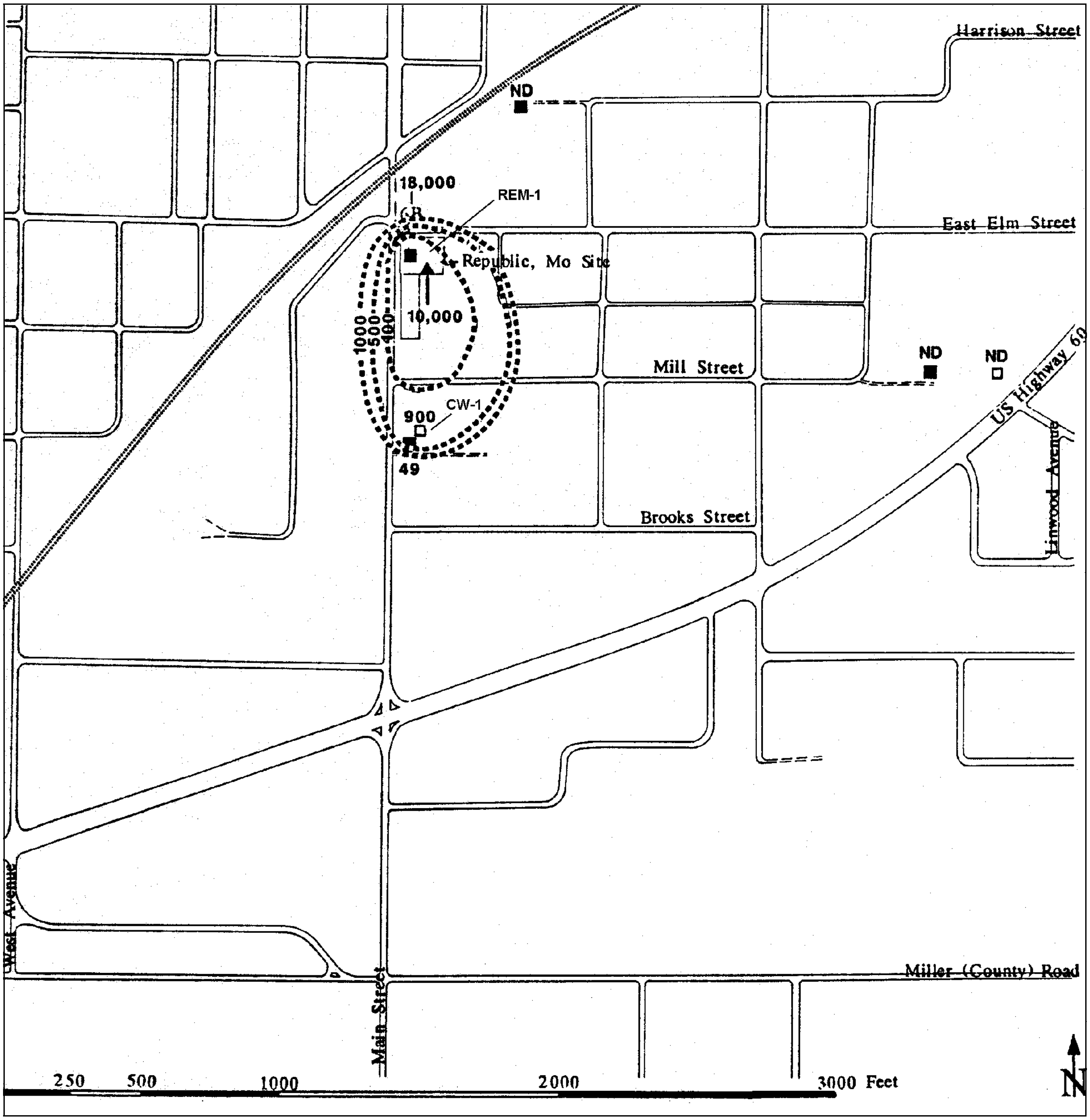

Figure 3. Initial Concentration Contour (μg/L) Map of Deep Bedrock, June 1989 [2]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Pump and treat with air stripping

Supplemental Treatment Technology

None

System Description and Operation [2, 3]

Table 2. Technical Well Data

Well Name	Unit Name	Depth (ft)	Ave. Yield (gal/min)
SSC-29	UFSB	90	1-3
SSC-30	UFSB	90	1.2-7
SSC-31	UFSB	90	1.8-17.4
SSC-6C	SBR	283	0.3-1.6
REM-2	SBR	331	.01-.42
CW-1	DBR	985	65
REM-1	DBR	600	55

Note: Average system yield is 49,493 gallons per day, taking into account the system operational time from 1993 to 1996.

Source: [2, 3]

- The groundwater extraction system at this site was installed in phases from 1987 to 1993. The initial system consisted of four on-site wells. Two were installed in the SBR unit and one in the DBR unit; the existing Municipal Well CW-1, which was contaminated with TCE, is the fourth well. In 1993, three additional wells were installed in UFSB, along the off-site portion of the plume.

- The extraction wells in each of the three hydrologic units are operated differently to ensure that hydraulic containment of the plume in that unit is maintained.

- UFSB wells are operated continuously to maintain an annual rolling average water level between 5 to 20 feet above the bottom of the well. The SBR wells are operated intermittently to maintain a level between 25 to 50 feet above the well bottom, with both wells pumping for a limited period every day. The DBR wells operate continuously.

- The on-site wells and SSC-30 discharge to the treatment system while the off-site wells discharge directly to the public sewer line where it is carried to and treated at the POTW. If the levels exceed discharge standards, the groundwater is routed to the air stripper for treatment. Monitors are installed at the points of discharge to selectively shut off when the discharge standard is violated [3].

- The state required pipes carrying extracted water with TCE concentrations levels greater than 100 ppb to be constructed of double-walled PVC, while lines carrying less contaminated water can be single-walled [3].

- Groundwater with TCE concentrations that exceed 200 µg/L is treated in a treatment system consisting of an equalization tank and two stripper towers set in a series [3].

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

- The equalization tank holds 960 gallons and serves to regulate the flow of water from the extraction wells that are pumping at different rates and frequencies [3].

- The two 23-foot air stripping towers are plumbed in series, each having an internal diameter of 37.25 inches. The towers are packed with PVC packing to a height of 13.5 feet. Air and groundwater are sent through the tower at a ratio of 750 to 1, respectively, and have a design flow rate of 150 to 175 gpm. Treated groundwater is then discharged to the local POTW. Effluent is monitored once every 90 days to ensure that discharge standards are being met [3, 4, 5].

- Air emissions from the stripping towers were monitored during the Pilot Program, conducted from October 1991 to January 1992. Emission levels remained below the state air standards, and no treatment of air emissions is required [3].

- The extraction and treatment system operations are monitored and controlled by a specialized software package. The software tracks and monitors system parameters, such as individual well pump rates and water levels, and water levels in the sanitary sewer. A telecommunications component of the software permits users to access the system from off-site locations with a modem. The software can control well pump rates to maintain the rolling average extraction levels required by the Consent Decree. The software also monitors the leak detectors installed along the pipelines and can turn off specific wells in the event of a leak. A meteorological station feeds external temperature and precipitation data to the software system to identify freezing or high water conditions that might affect treatment system operations [10].

- According to the PRP contractor, the integrated hardware and software data acquisition and control system results in significant cost savings for the project. Total estimated savings are at least $25,000 per year.

- Groundwater quality is monitored in all seven extraction wells and 13 monitoring wells. As of January 1996, the chemical monitoring frequency was reduced to annual. The UFSB unit has eight monitoring points, and the SBR and DBR units have six each. All wells are monitored quarterly for TCE. Groundwater levels are monitored daily, averaged, and reported as annual rolling averages on a quarterly basis. The Consent Decree specified that certain water levels above the well bottom must be maintained in the UFSB and SBR units to ensure hydraulic containment [6].

System Operation [2, 4, 5, 7]

- The total quantity of groundwater pumped from each unit is given below [7]:

	Volume Pumped (gallons)			
Year	**UFSB**	**SBR**	**DBR**	**All Units**
Pre-1993	Not available	Not available	123,563,609	123,563,609
1993	825,416	70,910	47,587,620	48,483,946
1994	3,058,415	107,200	39,727,669	42,893,284
1995	3,633,828	138,770	19,626,360	23,398,958
1996	3,505,324	115,756	9,468,533	13,089,613
March 1997	1,584,276	66,310	4,069,400	5,719,986
Total	12,607,259	498,946	244,043,191	257,149,396

- As of March 1997, the treatment system has been operational approximately 95% of the time. The majority of downtime is for routine maintenance of the pumps and the strippers. A small amount of downtime is due to updates to the software control system, and seasonal high water levels in the sanitary sewer that prevent discharge to the POTW [4, 5].

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation (Cont.)

- Pumping of contaminated groundwater began during the RI/FS in 1987. At that time, groundwater was extracted from CW-1 and treated in a rented air stripper (which was purchased in December 1987). Over the next two years, three additional wells were installed on site to provide influent to the air stripper. In late 1990, the air stripper was re-conditioned with new packing and piping. In 1993, three wells were installed in the off-site fracture zone. The effluent from these wells is discharged directly to the sanitary sewer [2, 5].

- The treatment system was shut down several times prior to 1994 because of freezing water in the strippers. During the first quarter of 1994, the stripper blowers were changed to link to the transfer pumps. This change allowed the blowers to operate only when there was water in the stripping towers. Since the switch, there has not been a freezing problem [5].

- Air stripping media has not been changed since operations began. The towers are cleaned twice in the summer with sodium hyperchlorite to prevent biofouling [10].

- The site operators have begun evaluating the feasibility of adding innovative technology to improve the efficiency of the remedial action. Soil vapor extraction and air sparging are two technologies currently under review, both for their efficacy in reducing concentrations in soils and groundwater and for their ability to stimulate bioremediation [4, 5]. At the time of this report, no decisions had been made. Currently, the site operators are installing a 485-foot horizontal well beneath Main Street and above the Main Street fracture.

Operating Parameters Affecting Treatment Cost or Performance

The major operating parameter affecting cost or performance for this technology is the pumping rate. Table 3 presents the values measured for this and other operating parameters.

Table 3. Operating Parameters

Parameter	Value
Range of Treatment System Pumping Rates	19-105 gpm
Performance Standard	Discharge from any one point not to exceed 200 µg/L TCE
Remedial Goal	TCE 5 µg/l

Source: [1,3,7]

TREATMENT SYSTEM PERFORMANCE (CONT.)

Timeline

Table 4 presents a timeline for this remedial project.

Table 4. Project Timeline

Start Date	End Date	Activity
1987	1989	RI/FS and interim groundwater treatment conducted
Sept 1989	---	ROD issued
1991	1992	Remedial design performed
1993	---	UFSB off-site wells installed
Jan 1993	---	System operation began
Jan 1993	---	Quarterly monitoring begins
Sept 1993	---	Additional UFSB extraction well, SSC-31, installed
1995	---	Water sampling in municipal distribution reduced to biannual; chemical monitoring reduced to semiannual
Jan 1996	---	Chemical monitoring reduced to annual

Source: [6]

TREATMENT SYSTEM PERFORMANCE

Cleanup Goals/Standards [1]

The remedial goals for this site are to reduce the TCE concentration in groundwater to 5 µg/L and maintain hydraulic control over the groundwater plume. These goals must be met throughout all affected aquifers.

Treatment Performance Goals [6]

Performance goals for the system were delineated in the Consent Decree and were formulated in terms of required pump rates and water levels to ensure hydraulic containment of the plume. Specific goals were:

- To ensure that TCE levels in individual discharge points to the POTW are below 200 µg/L.
- To maintain an average water level above well bottom in UFSB wells of 5 to 20 feet.
- To maintain an average water level above well bottom in SBR wells of 25 to 50 feet.
- To maintain an average annual pump rate from the DBR wells of 75 gpm.
- Total sewer discharge cannot exceed 200 gpm from all sewer discharge locations.

Performance Data Assessment

- No contaminants have been detected in downgradient monitoring wells nor in Robert Spring since 1993 when the UFSB wells were installed, and plume containment appears to have been achieved [7].
- Contaminant removal through the air stripper is shown in Figure 4. From March 1988 through March 1997, 2,754 lbs of TCE were removed from the groundwater. Two periods of increased removal were noted.

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Assessment (Cont.)

In the first quarter of 1989, the two SBR wells were installed, and mass flux increased from less than 2 lb/day to 5.3 lb/day. By the following quarter, it had returned to its previous level. When the UFSB wells were installed in early 1993, the mass removal rate rose abruptly from less than 2 lb/day to 4.8 lb/day, and reached 25.1 lb/day by the final quarter of 1993. However, by the end of the first quarter of 1994, the rate of removal had returned to less than 2 lb/day [7].

- Figure 5 illustrates changes in the TCE concentrations found in the DBR wells over time. Groundwater monitoring results indicate that contaminant concentrations in one DBR well have been reduced below treatment goals. TCE concentrations in CW-1, located at the toe of the DBR plume, have declined steadily, and, as of April 1993, have remained below detection limits. Contaminant levels in REM-1, located in the source area, were high in 1987 (4,758 µg/L), and had dropped to approximately 100 µg/L in the last quarter of 1996 [7, 8]. Additionally, the reduction in concentrations in REM-1 demonstrates the pathway contributing contaminants into the DBR has been shut off and concentrations near the source have been reduced by a factor of 40 [11].

- The data in Figure 6 show the change in TCE concentrations in the on-site SBR wells. Concentrations have declined regularly in well REM-2 from 1987 through 1996, they have varied in SCC-6C, going through cycles over the period [7, 8].

- Figures 7 through 9 present changes in TCE concentrations in three different areas of the UFSB plume: the source, mid-plume, and the toe. As shown in Figure 5, TCE concentrations in the source area have clearly declined in both wells since 1987. The largest decline was seen in SSC-11, which dropped from 31,067 µg/L in 1987 to 3,200 µg/L at the end of 1996. Contamination levels at mid-plume have not reduced appreciably from their levels in 1993, and have increased significantly in SSC-20. However, a 1987 sampling event found a level of 66,560 µg/L in that well; therefore, despite the rise in TCE concentrations in this well from 1993 to 1996, the level of TCE in SSC-20 in the final quarter of 1996 was substantially lower than the 1987 level. At the toe of the plume, TCE concentrations have declined to less than 50 µg/L in wells SSC-31, SSC-26, and SSC-27 [7, 8].

TREATMENT SYSTEM PERFORMANCE (CONT.)

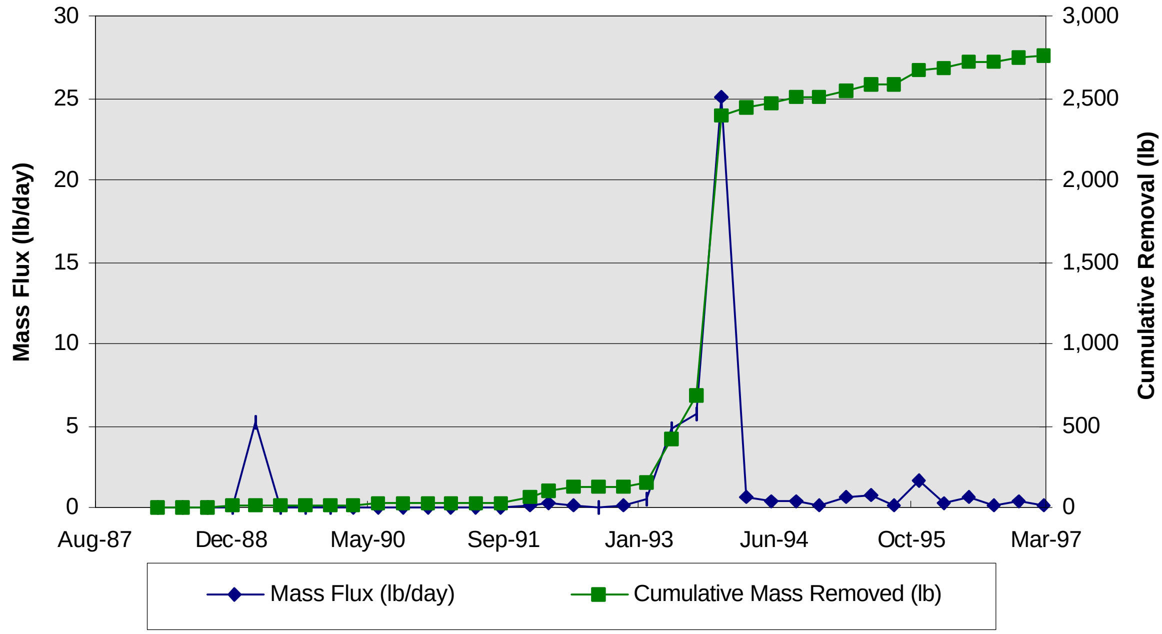

Figure 4. Mass Flux Rate and Cumulative Total Contaminant Removal from March 1988 to March 1997 [7]

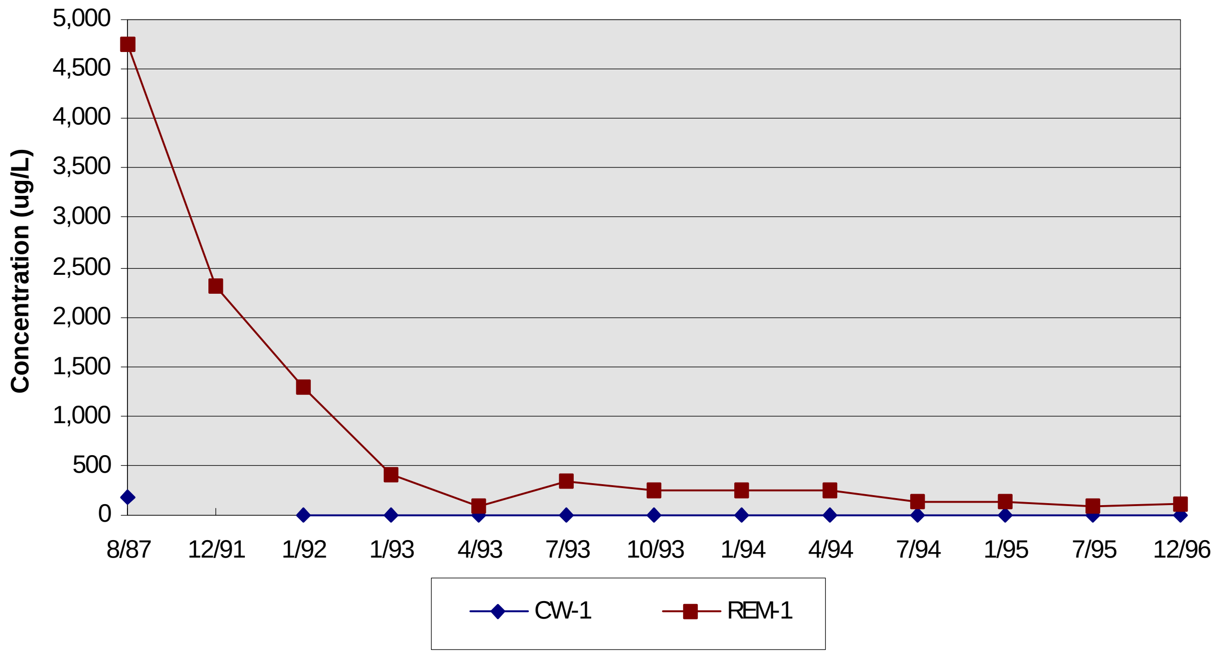

Figure 5. TCE Groundwater Concentrations in DBR Wells, August 1987 to December 1996 [7]

TREATMENT SYSTEM PERFORMANCE (CONT.)

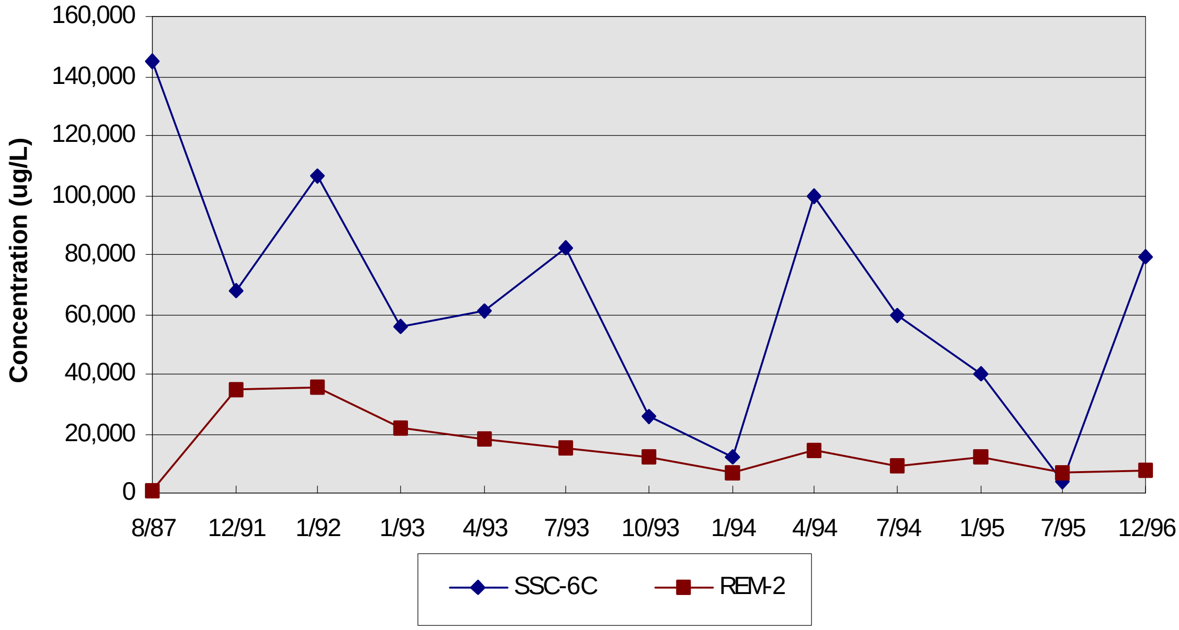

Figure 6. TCE Groundwater Concentrations in SBR Wells, August 1987 to December 1996 [7]

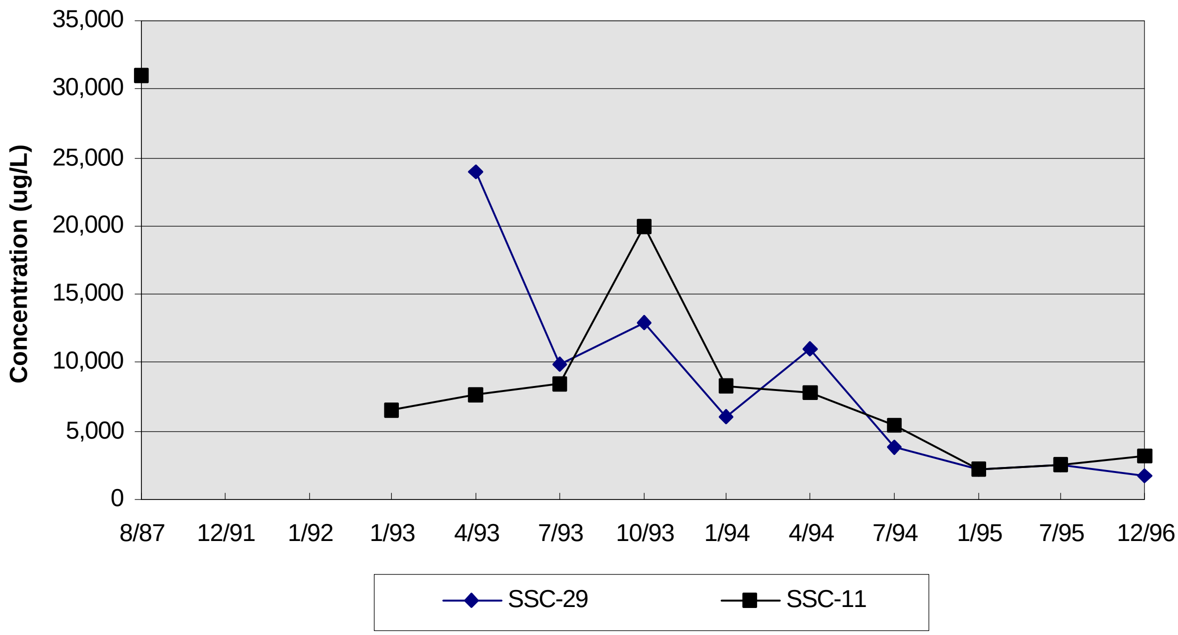

Figure 7. TCE Groundwater Concentrations in UFSB Wells (Source Area), August 1987 to December 1996 [7]

TREATMENT SYSTEM PERFORMANCE (CONT.)

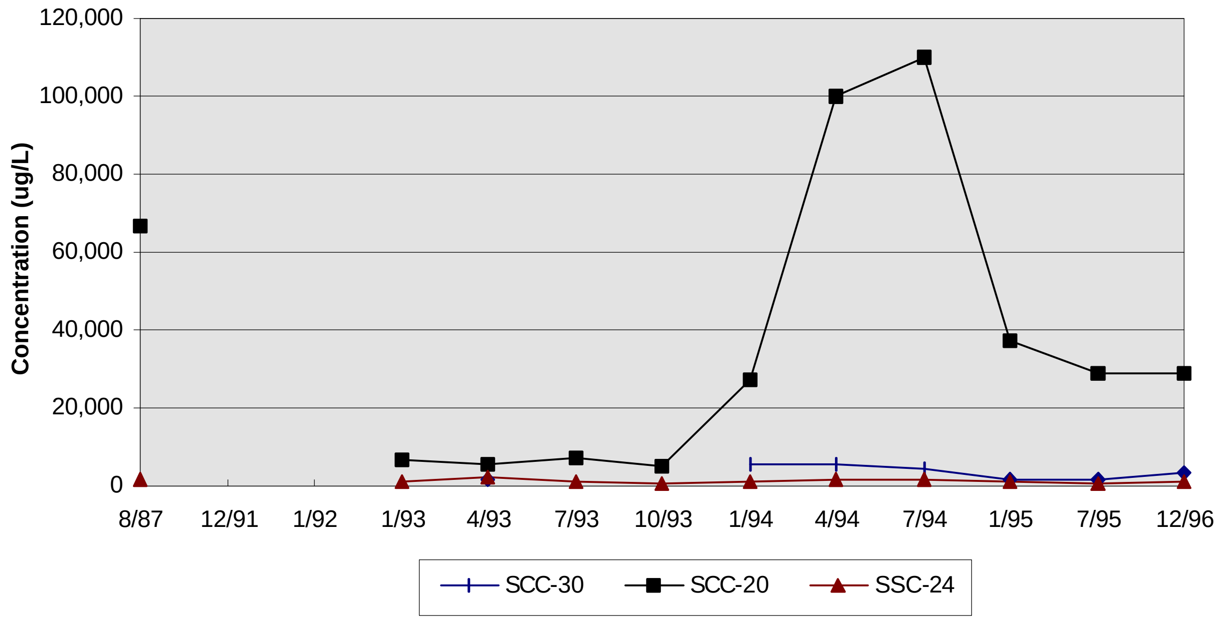

Figure 8. TCE Groundwater Concentrations in UFSB Wells (Mid-Plume Area), August 1987 to December 1996 [7]

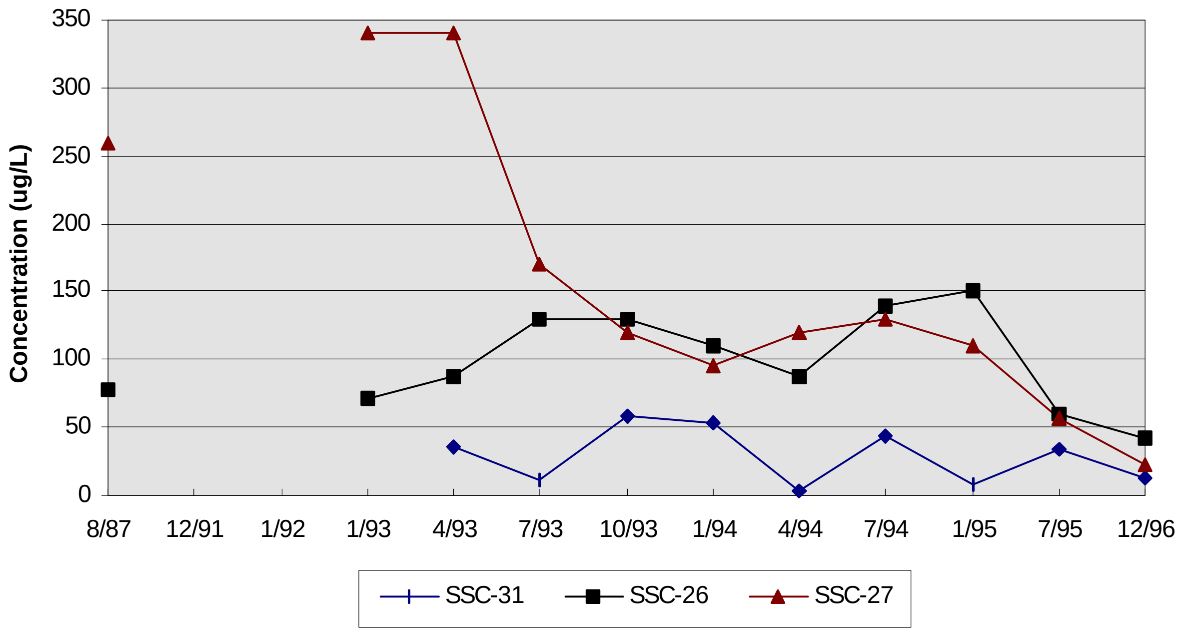

Figure 9. TCE Groundwater Concentrations in UFSB Wells (Toe Area), August 1987 to December 1996 [7]

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Completeness

- Performance monitoring data are only available for TCE because it is one to three orders of magnitude greater than other constituents and this was chosen as the indicator compound to be monitored. Furthermore, the amount of TCE removed by the POTW is not available. Therefore, the estimated mass removed through the air stripper represents an underestimate of total contamination removed during this remedial action.

- Air stripper influent monitoring data, collected quarterly, are available from January 1993 to the final quarter of 1996; these data were used in Figure 4. To generate data for the period from 1987 to 1993, sporadic monitoring in wells, CW-1 and REM-1 were combined with monthly pumping volumes to generate estimates of contaminant removal in these two wells over this period.

- Groundwater quality was monitored in all wells on a quarterly basis from January 1993 to January 1996. At that time, the monitoring frequency was changed to semi-annual. Data in Figures 5 to 9 represent all available data for the wells shown.

Performance Data Quality

The QA/QC program used throughout the remedial action met the EPA and the State of Missouri requirements. All monitoring was performed using EPA Method 8010, as set out in the Consent Decree, and the site operator did not note any exceptions to the QA/QC protocols. [10]

TREATMENT SYSTEM COST

Procurement Process

Solids States Circuits, and later the Missouri Remedial Action Corporation (MRAC), a company founded by the PRPs at this site (other sites as well), have contracted with a series of companies to construct and operate the remedial system at this site. Presently, the system is being operated by Chatman Associates of Lawrence, Kansas.

Cost Analysis

All costs for design, construction and operation of the treatment system at this site were borne by MRAC.

TREATMENT SYSTEM COST (CONT.)

Capital Costs [6]

Remedial Construction	
Engineering and Site Management	$57,329
DBR/SBR Extraction Wells	Not Available
UFSB Extraction Wells and Piping	$786,085
Air Stripper	
Rental/Purchase	$49,290
Rehabilitation	$40,266
Total Remedial Construction	**$893,666**

Operating Costs [6]

Project Management	$386,000
Data Management	$134,000
Monitoring/Analysis	$282,000
Utilities	$370,700
Periodic Maintenance	$146,600
Reporting	$152,400
Other	$145,600
Cumulative Operating Cost through 6/30/97	$1,616,700

Annual Operating Costs

1992	$104,121.69
1993	$431,410.13
1994	$264,246.69
1995	$272,721.17
1996	$215,832.75
1997	$255,390.00
	$1,543,722.43

Other Costs [6]

Remedial Design	Not Available
EPA/DNR Oversight	$243,771

Cost Sensitivities

- There were no significant changes to the construction scope of work that increased the capital cost by more than 10 percent [5].
- There have been no significant events that have increased or decreased the cost of operations more than was expected [4].

Cost Data Quality

Actual capital and operations and maintenance cost data are available from the responsible party for this application. Limited information on the items included in the total capital costs was provided. The individual costs of remedial design and the installation of the DBR and SBR wells were not available because they were tracked as part of the RI/FS [5].

OBSERVATIONS AND LESSONS LEARNED

- According to the PRP contractor, the remedy, as operated, has eliminated groundwater pathways to human populations and the environment; ensured that municipal water supply operations are not impacted; ensured safe operation of the remediation system during times of high sewer flow; ensured minimal human exposure; and kept annual O&M manpower costs to less than half of what was originally projected. In addition, the PRP contractor noted that the pumping rate for wells in the DBR unit was reduced 80 percent (from 75 gpm to 15 gpm) [11].

OBSERVATIONS AND LESSONS LEARNED (CONT.)

- Project management costs for both construction and operations were about 6 percent of the respective totals. If periodic reporting is included, the percentage rises to 18 percent. This is a relatively low percentage for project management, which can be attributed, in part, to the active role played by the MRAC engineer. [6]

- Total cost for the remedial action at this site were $2,510,400 ($1,616,700 in O&M costs and $893,700 in construction costs) which corresponds to $913 per pound of contaminant removed and $10 per 1,000 gallons treated.

- TCE concentrations in some of the wells have decreased from 1987 to 1996, and are below the cleanup goal in one well; however, TCE concentrations in most wells remain well above the cleanup goal.

- Contaminant removal rates through this system have been relatively low, less than two pounds of contaminant per day, on average. This low rate is largely due to the hydrogeology of the site, which is dominated by tight clay materials and solution-weathered limestone. In both materials, contaminants are difficult to remove [5].

- TCE levels in CW-1, the first well to be contaminated, declined rapidly after the original extraction system came online. The site engineer stated that pumping in CW-1 prior to the RI had established groundwater flow paths that drew contamination from the basement dry well towards CW-1. Once the source removal actions were complete, the dissolved contamination remaining between the source area and CW-1 defined a narrow path that was rapidly remediated by pumping CW-1 [5].

- The site engineer believes that DNAPL is not likely to be present at the site. No DNAPL has ever been identified, despite several extensive groundwater assessments. However, concentrations in several wells remain high, and in some wells are presently higher than 1 percent of the solubility limit for TCE.

- To enhance the remedial effort, site operators are evaluating innovative technologies at the time of this report. They are considering installing an air sparging system using a horizontal well in the fracture zone of the UFSB. Placement of the horizontal well along the fracture zone would force the groundwater pressure gradients towards the SBF extraction wells in the highest part of the plume, enhancing VOC removal from the groundwater in that stage of the plume. The well would be designed and constructed for two other uses: as a nutrient injection well to enhance natural bioremediation in the fracture system, and as an air sparging well.

- According to the site engineer, institutional constraints that restricted the operator's ability to use reinjection at this site may have increased the time required for site remediation more than any other single factor [11].

REFERENCES

1. Record of Decision for Solid States Circuits, Republic, MO, U.S. Environmental Protection Agency. July 1989.
2. Remedial Investigation Report for the Republic, Missouri Site, Geraghty & Miller. June 1989.
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Analysis Preparation

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